AN1783
APPLICATION NOTE

HOW TO MAKE FIRE-WIRE COMMUNICATION PORT SAFE?

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Video-media equipment growth has lead manufacturers to use fast transmission buses in order to share information quickly and easily.

In many cases, video equipment use Fire-Wire link (IEEE1394) which brings the following features:

- Up to 63 devices can be plugged on the bus
- 400Mb/s data transmission rate
- Hot plugging
- Power through the cable
- Plug-and-play
- Low cost cabling
- Low implementation cost

As a matter of fact, this race for fast transmission and small compact video machines (cameras, mobiles, video equipment) has brought more and more integrated and sensitive electronic devices at the same time. As a result, on one hand, protection devices have been required to make the system more robust regarding ESD while, on the other hand, line adaptation have been implemented to prevent fast signal distortion due to high data rate transmission across non ideal elements.

ST1394-01SC6 is one of those devices that combine both ESD protection and line termination at a time in one chip especially designed for Fire-Wire transmission.

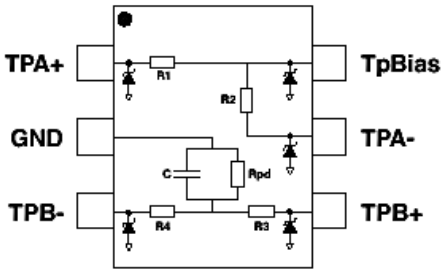
Its ± 4kV ESD IEC61000-4-2 compliance and small package (1.5x2.8mm) makes it very convenient for IEEE1394 link.

The following internal diagram gives an idea of its characteristics.

We can notice on *figure 1* the following points:

- ESD protection is performed with clamping diodes located at each line side.
- RC elements realize line termination at each data lines
- Moreover, intrinsic clamping diode capacitors offers RF rejection for GSM bandwidth.

Fig. 1: ST1394-01SC6 internal diagram.



Lines	TPA+	TPA-	TPB+	TPB-	Rpd	GND	Zener Capacitance
Names	R1	R2	R3	R4	R5	C	CZ
Value	55Ω	55Ω	55Ω	55Ω	5kΩ	250pF	5pF
Tolerance	Typ.	Typ.	Typ.	Typ.	20%	20%	Max.
Matching	Matching between 55Ω Resistor at ± 1% max.						

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ST1394-01SC6 BOARD PLACEMENT RECOMMANDATIONS

Whatever the protection device at Fire Wire connector, it is known that upon ESD strike occurrence, a remaining over voltage is applied at sensitive IC side. In main cases a small part of this over voltage is coming from the clamping of the protection diode and a larger part from the copper track that connects component altogether. For this reason it is important also to focus on the way component are routed.

The way the ST1394-01SC6 is mounted on the Fire-Wire communication printed board is also a major concern. This will affect the ESD and line termination efficiency. Keep in mind when facing +4kV ESD surge (IEC61000-4-2, level 2), a 10mm long; 0,5mn wide; 35µm thick copper track will induce about 70V!! over-voltage due to track parasitic inductance.

Indeed, fast di/dt induced by the ESD IEC61000-4-2 level 2 brings the following calculation:

- The ESD surge has a step rise time of 0.7ns minimum.
- The level 2 of the ESD test table stands for 4kV air discharge and the internal series resistance of the equivalent ESD generator is 330 ohms, thus the peak current induced by the 4kV surge is roughly 12A
- A 1mm, 35µm thick, 0.5mm wide is 0.4nH

Then considering a 10mm; 35µm; 0.5mm copper track, the voltage drop along this track comes up with:

$$V = L\frac{dI}{dt}; \text{ then it is } V = 10 \times 0.4 \times 10^{-9}\frac{12.1}{0.7 \times 10^{-9}} = 70V!!$$

So shorter the tracks, better the ESD suppression.

Next figures 2 and 3 give an idea of component placement on a printed circuit board:

Fig. 2: Bad layout.

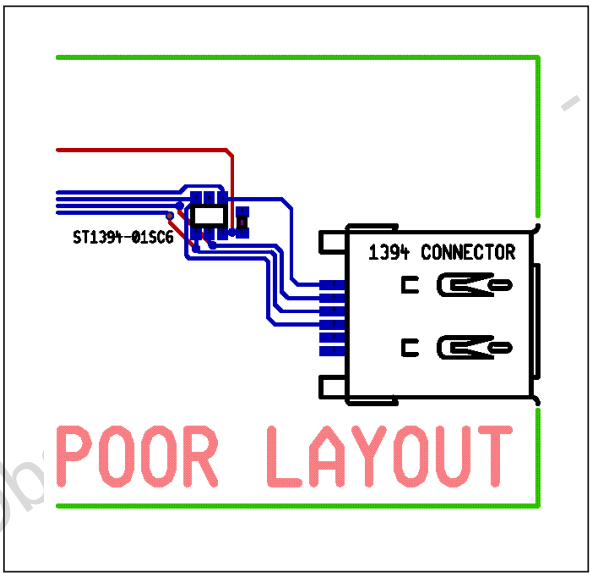
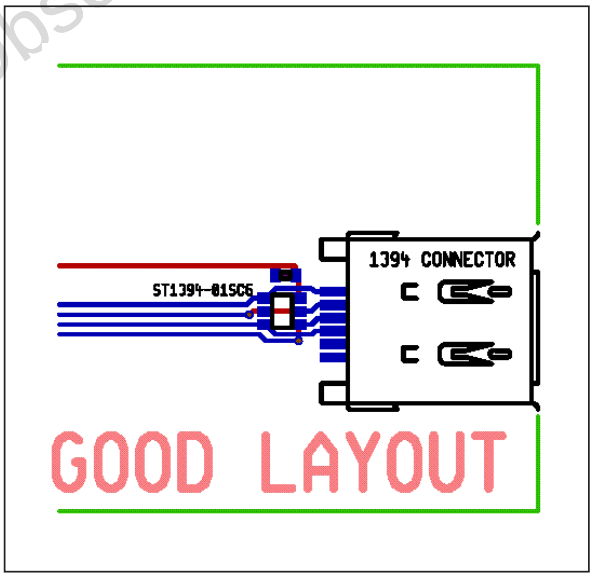


Fig. 3: Good layout.



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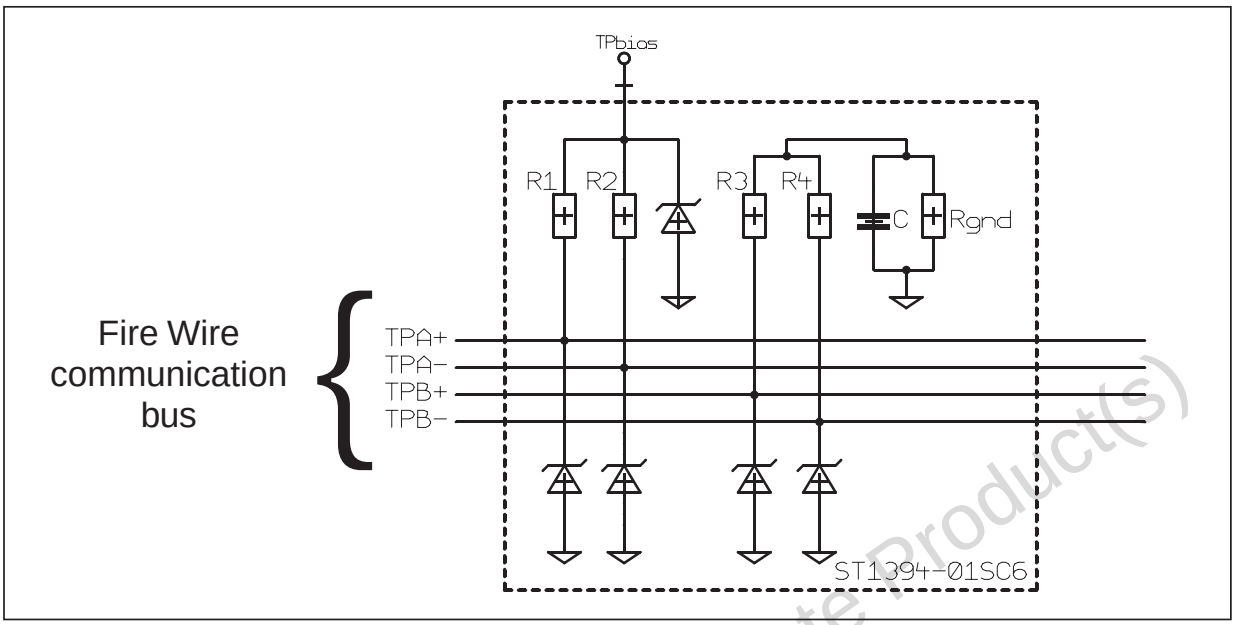
ESD PROTECTION

The ST1394-01SC6 complies with IEC61000-4-2 standard, level 2, air discharge surge test (± 4kV).
The next figure shows the way the ST1394-01SC6 is connected to Fire Wire communication port:

Fig. 4: ST1394-01SC6 connection diagram.



When the surge is applied at the Fire-Wire communication port, the ST1394-01SC6 eliminates the over-voltage like shown further:

The way it works!

Upon ESD occurrence (*cf. fig. 5*), Z1 diode clamps the surge and the remaining voltage at its terminations is:

$$V1 = V_{BR} + R_d \times I1 \equiv V_{BR} + 12V$$

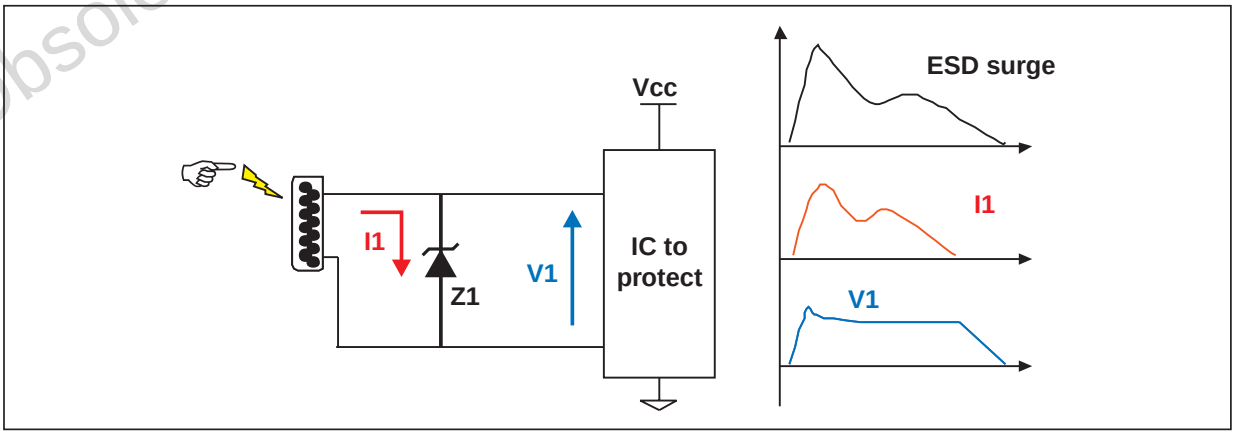
Considering $I1 \approx 12A$ (≈4000V/330Ω per IEC61000-4-2 level 2)

V_{BR} = Z1; ST1394-01SC6 internal diode breakdown voltage

R_d = dynamic resistance =1Ω for ST1394-01SC6

That means the remaining over-voltage at the ST1394-01SC6 input line is 12V above Z1 diode breaking voltage.

Fig. 5: ESD occurence.



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WHAT HAPPENS IN A PRACTICAL CASE?

Fig. 6: Test set-up picture.

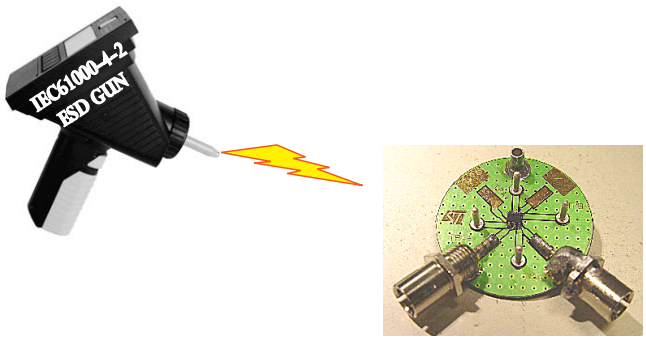


Fig. 7: Remaining over voltage at ST1394-01SC6 input terminations when +4kV is applied.

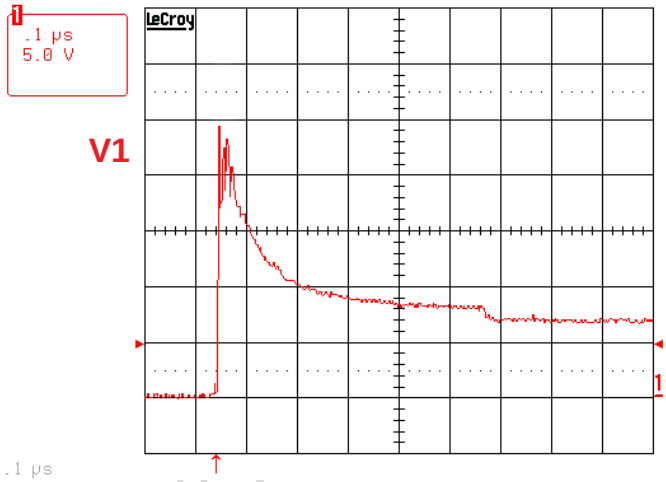
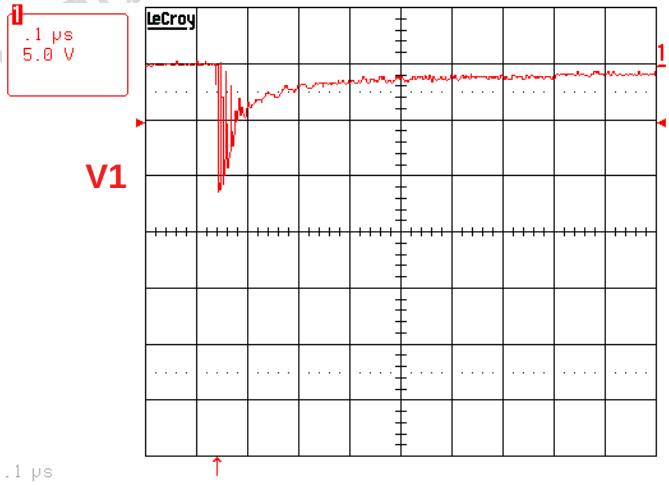


Fig. 8: Remaining over voltage at ST1394-01SC6 input terminations when -4kV is applied.



As a result, last figures show the remaining over voltage at the ST1394-01SC6 output is quite low and that way ensures a very efficient protection against ± 4kV ESD strike.

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LINE TERMINATION

The ST1394-01SC6 has an internal circuitry that is convenient for line termination.

Indeed non-adapted line load would generate signal distortion and in some cases make big overshoots over data signal transmission, exposing down-stream ICs to hazardous voltages.

This phenomenon is simply explained in next diagram where a data line transmission is given through Pspice model.

This shows a Transmitter that communicates with a Receiver via a transmission line.

In case of high-speed data rates, a poor receiver adaptation would create signal distortion as shown in next *figure 11*.

Fig. 9: Pspice model of a data line transmission with no adaptation**.**

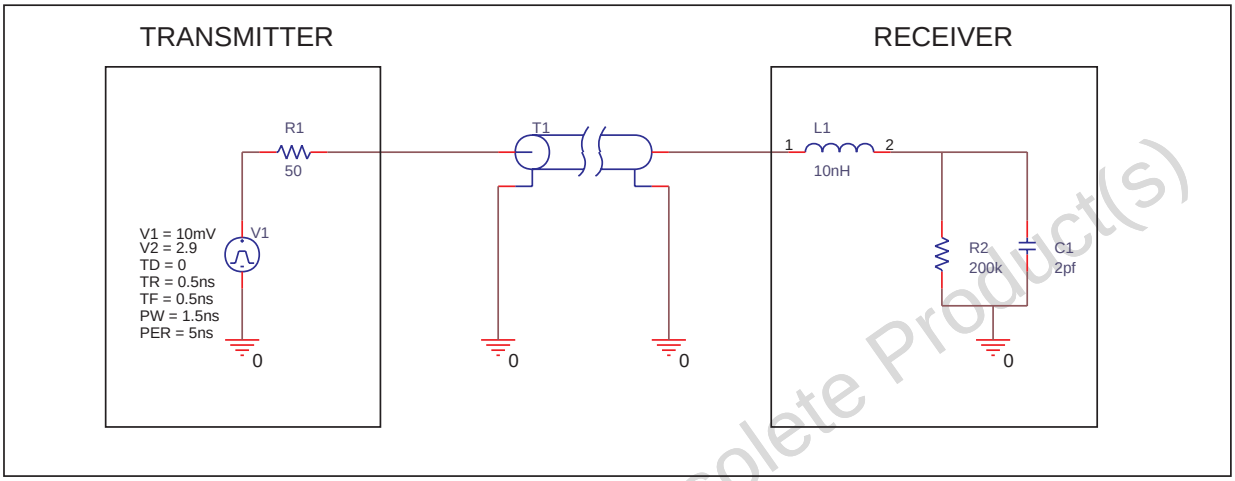
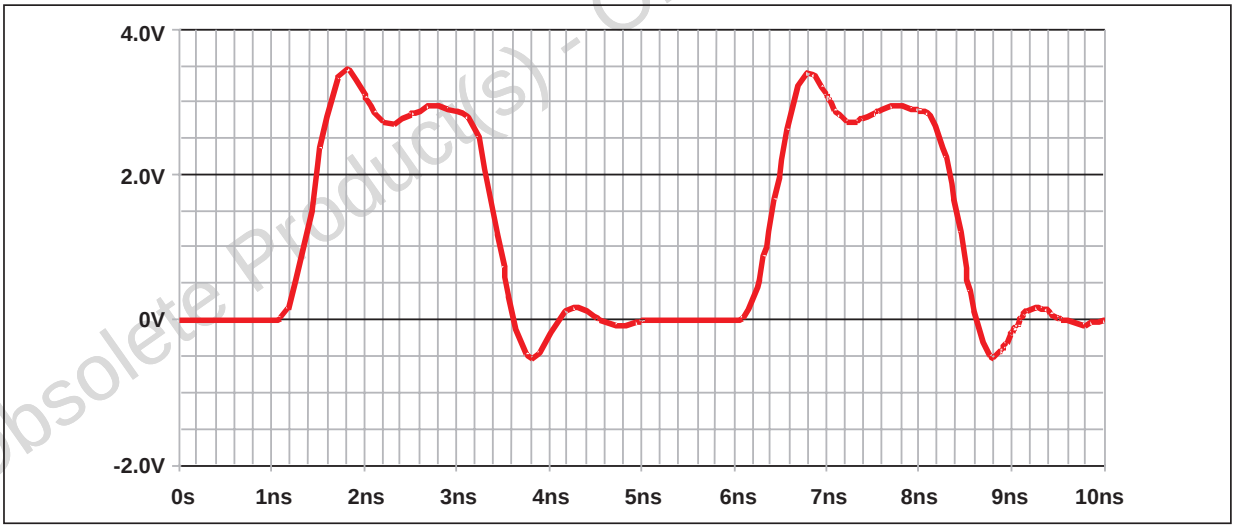


Fig. 10: Poor adaptation on data transmission signal induces overshoots.



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Now, if we consider the same Pspice model where the Transmitter is communicating with a Receiver using the ST1394-01SC6 device in between, the data signal transmission would have almost no distortion as on next page:

Fig. 11: Pspice model of a Receiver when using ST1394-01SC6.

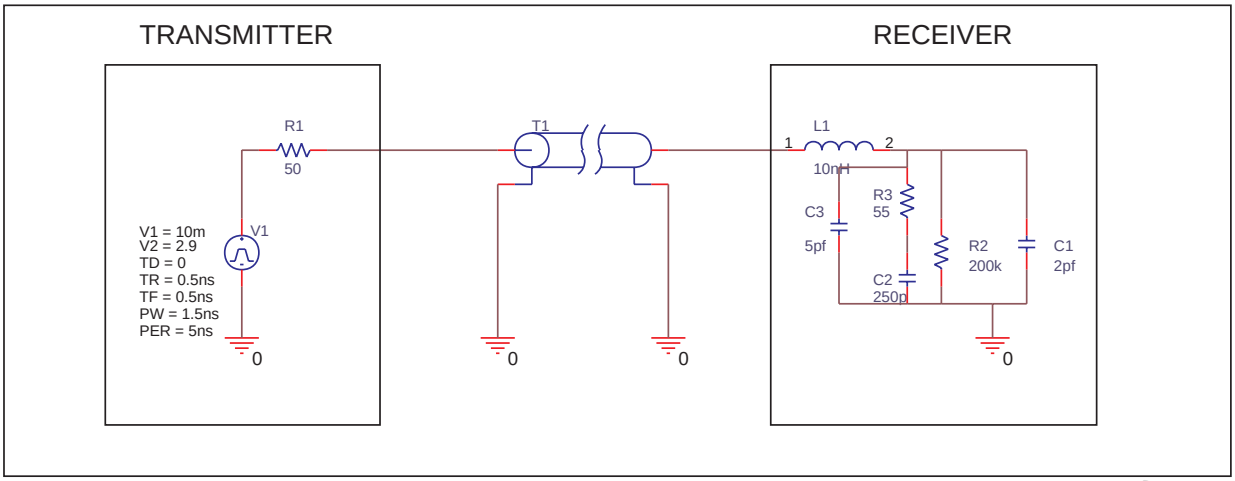
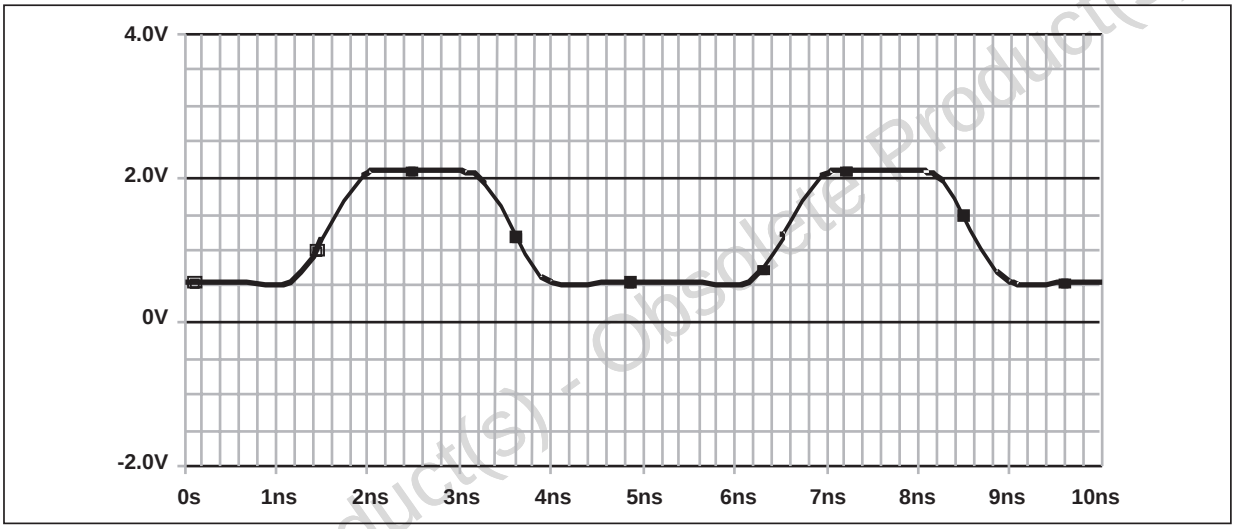


Fig. 12: Signal behavior change in case of adapted transmission line.



This Line Adaptation chapter tells us how important it is to implement line termination elements on IEEE1394 communication port and how ST1394-01SC6 performs in that case. It is also noticeable that line adaptation is better realized since down-stream ICs are **as close as possible to ST1394-01SC6 device**.

As a results, ST1394-01SC6 has to be as close as possible to the IEEE1394 connector for ESD consideration, and down-stream ICs have to be located as close as possible to the ST1394-01SC6 for line termination consideration as well.

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RF FILTER

Among all the benefits the ST1394-01SC6 offers, there is one that allows the designer to get a low-pass filter close to the IEEE1394 communication port especially dedicated to GSM bandwidth radiation.

The way the frequency response is measured is shown below:

Fig. 13: Frequency response measurement set-up using HP8753E VNA (Vector Network Analyzer).

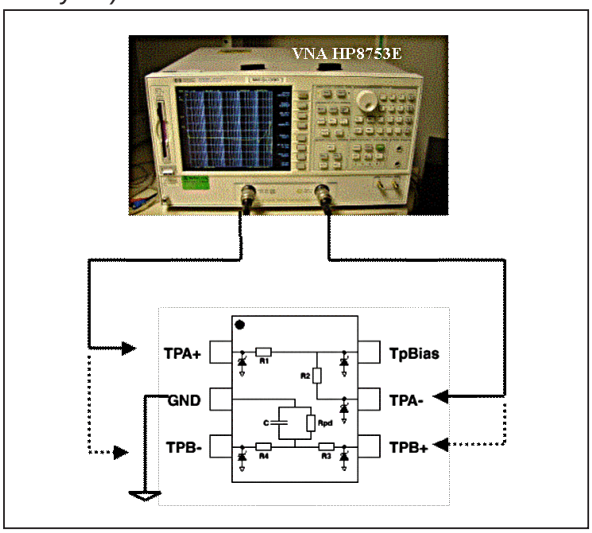
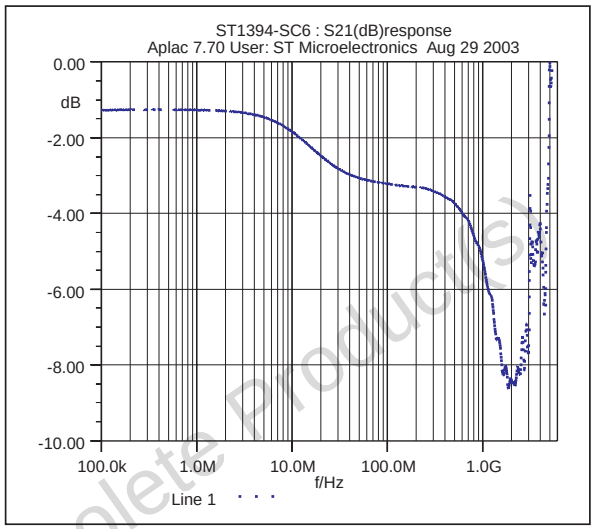


Fig. 14: Frequency response behavior on TPA line.

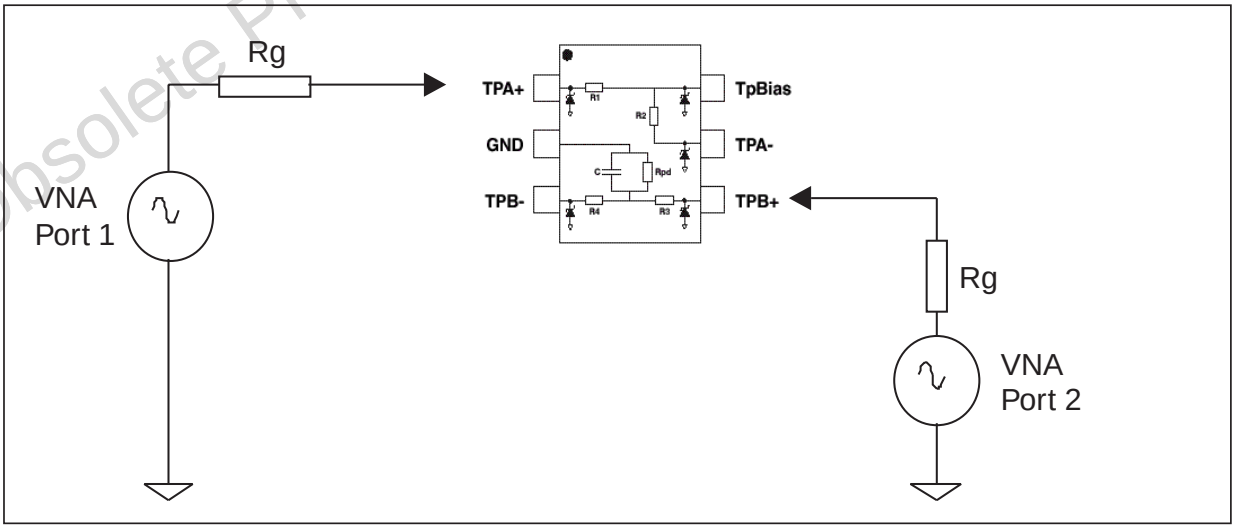


Thus frequency behavior is monitored and typical TPA or TPB response is given in *figure 14*.

Since one ST1394-01SC6 device manages two data transmission lines, some cross-talk phenomenon can be considered. This phenomenon could be explained by interferences from one line to the other due to internal undesirable coupling elements like parasitic capacitors or whatever.

Cross-talk analysis consists in checking the impact of data transmission of one line on the other during digital communication. The test set-up schematic given beneath tells more about it:

Fig. 15: Cross-talk set-up.



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This cross-talk measurement figure shows the parasitic disturbance is about -40dB for a 400Mb/s signal from one line to the other.

As long as frequency measurement is considered, caution must be taken in the way the measurements are performed. And particularly regarding the PCB in order to minimize insertion losses and reflection phenomena mainly due to the test board. It should have the following features:

- short tracks, 50Ω impedance adapted
- coplanar structure, meaning ground plate located at the back and top sides of the test PCB
- ground vias on the entire pcb surface and all along the access tracks (that connect the device under test to the VNA equipment)
- SMA connector located at the edge of the test PCB.

A test board example is shown in the next *figure 17*:

Fig. 16: Cross-talk response between one line and the other with ST1394-01SC6 device versus frequency**.**

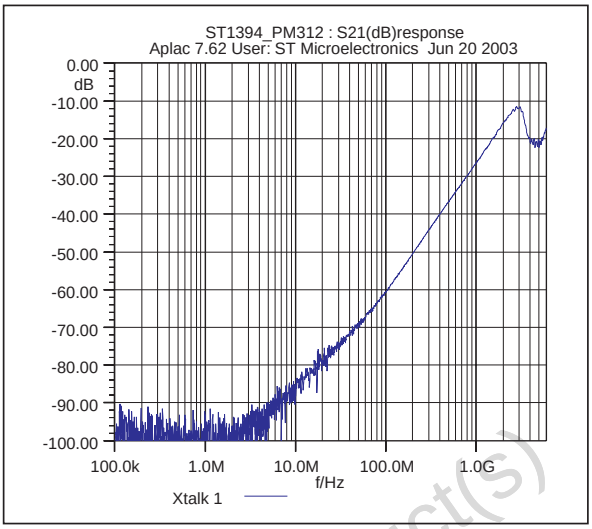


Fig. 17: RF test board picture (note the unused lines are 50Ω loaded).

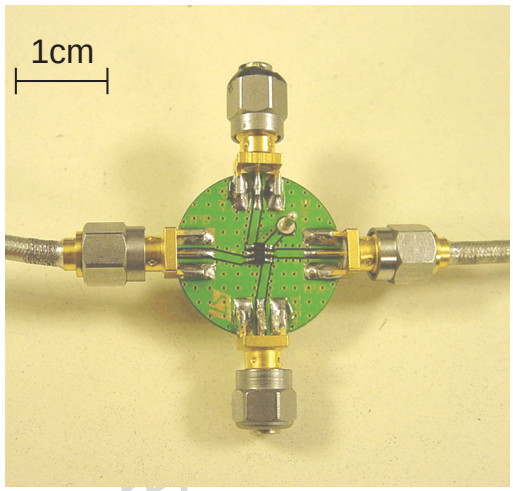
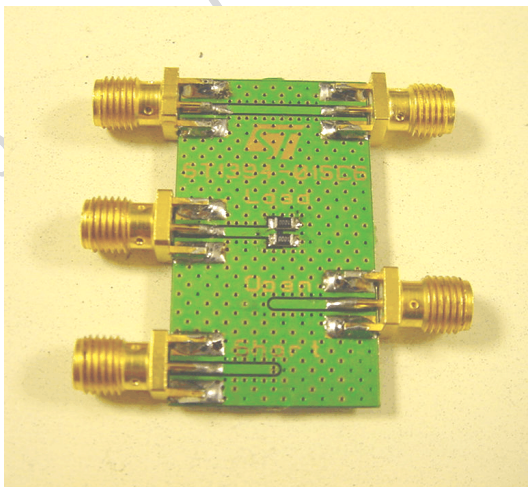


Fig. 18: Calibration board for ST1394-01SC6 frequency response board analysis.



This is not all, by the way the VNA: it needs to be calibrated before the measurements are performed. This imposes the use of a special calibration board that will previously set-up the analyzer and provides it the test PCB characteristics. Those latter would be subtracted to the final measurements.

Typical calibration board developed for the ST1394-01SC6 frequency response board measurement is given in *figure 18*.

Once "Full two port" calibration is performed on VNA equipment, the ST1394-01SC6 frequency response analysis can be done.

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CONCLUSION

Fire-Wire communication port systems require ESD protection due to the possibility of external device plugging, line termination due to fast data signal transmission in imperfect cable elements, GSM parasitic frequency cut-off because this transmission connection can be used in mobiles environment.

As shown and described in this article, the ST1394-01SC6 device has been especially developed for IEEE1394 communication port in order to fulfill:

- ESD IEC61000-4-2 protection thanks to internal protection diodes
- Line adaptation with integrated RC components
- GSM bandwidth frequency cut-off
- Easy implementation feature due to small SOT23-6L package

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